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ABSTRACT

The purpose of this study was to: (1) assess the reasoning levels of students using the Longeot Test; (2) compare the background of each student with the student's reasoning ability; and (3) identify which factors would best determine a student's reasoning level on the Longeot Test. The sample consisted of 636 students (336 females and 300 males) from nine schools located in the Upper Cumberland Region of Tennessee. Materials used for the study included the Longeot Test, standardized test scores (obtained for 501 students), and student background information, including age, sex, educational level of parents, and type of science course students were taking, i.e., biology (N=220), general science (N=110), chemistry (N=127), physical science (N=119), and physics (N=60). Results indicate that these variables affected student performance on the Longeot Test. In addition, results showed that a greater percentage of formal thinkers were male (53.7 percent) as opposed to female (46.3 percent). The significant differences found in correlating these variables support other research indicating the presence of two developmental stages in adolescence, that males score higher on a test of reasoning ability based on a Piagetian model than females, and that there is a positive correlation between achievement level and reasoning level. (JN)

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# A COMPARISON OF LEVELS OF COGNITIVE THOUGHT DETERMINED BY THE LONGEOT TEST AND ACHIEVEMENT LEVELS OF SECONDARY SCHOOL SCIENCE STUDENTS

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A Research Paper

Presented at

The Mid-Atlantic AETS Meeting

Pineville, Kentucky

by

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# Chapter I

## Introduction

One of the common interests of educators is how their students learn. There are many learning theories that explain how learning occurs and the cognitive theory of development of Piaget has become one of the more influential of these theories especially for educators concerned with higher cognitive levels. In fact, Piagetian ideas have dramatically changed the way educators regard the mental growth of children (Elkind, 1974). To take advantage of the significant contribution of Piaget to learning theory teachers need a basic knowledge of Piagetian theory, an appreciation of its impact on education, and tools for assessing the mental growth of students which they are responsible for directing.

## Background of Piagetian Theory

As a cognitive learning theorist, Piaget has emphasized the development of mental processes in the individual. The significant contribution of his theory to educators is his concern with the qualitative aspects of this development and the idea that there is a necessary progression from one level of development to another - in stages. Regardless of the age at which a child reaches a particular stage he cannot reach that stage without having first mastered earlier stages (Inhelder & Piaget, 1958).

The two periods of intellectual development with which this research deals are the period of concrete operations and the period of formal operations. Each of these periods are character-

ized by reasoning patterns that are used by the individual to classify observations, interpret data, draw conclusions and make predictions (Karplus, Lawson, Wollman, Appel, Bernoff, Howe, Rusch, and Sullivan, 1977). In concrete thought, which begins to be observed between seven and eleven years of age, the student needs reference to objects, familiar actions and observable properties. He uses classification, conservation, serial ordering, and one-to-one correspondence, and he is not aware of his own reasoning. In formal thought, which begins to be observed between eleven and fifteen years of age, the individual can reason with concrete and formal concepts, relationships, intangible properties and theories. He applies combinatorial, classification, conservation, serial ordering and proportional reasoning in relation to intangible items, and he is aware of his own reasoning. There is a shift of emphasis in student thought from the real to the possible. The formal thinking student can approach a problem by trying to imagine all the possible relationships in a given body of data. Then using logical analysis and experimental verification, he can determine which of these possible relationships actually hold true. This student exhibits hypothetico-deductive thinking.

With recent research indicating that perhaps 40 to 75 percent of sceondary school students have not yet reached the level of formal thought (Renner, Stafford, Lawson, McKinnon, Friot, and Kellogg, 1976), the assumption cannot be made that students are formal thinkers and, therefore, capable of understanding abstract concepts. Since much of the new curricula

assumes formal operational thought (Kohlberg and Gilligan, 1971) and is beyond the level of student understanding (Renner et al., 1976), teachers should be aware prior to instruction of what their students will be able to successfully comprehend.

In relating Piagetian theory to science education it should be determined which students need the "hands on" approach to understand science concepts. What reasoning abilities is education trying to foster in the secondary student by encouraging the manipulation of objects and step-by-step instructional packets in the science lab? Would it not help the teacher to know, in advance, which students can reason logically and form theories without the constant need to work with concrete objects in lab experiences?

Until recently, more attention has been given to the implications of Piagetian theory at the elementary level than at the secondary level because the adolescents Piaget observed seemed to perform formal operations (Coulter, Williams, and Schulz, 1981). But since it has been shown in our country (Lawson & Renner, 1975; Cantu & Herron, 1978) that fifty percent or more of graduating senior high school students have not achieved formal operational ability, a closer look must be taken at where the student lies on the continuum of mental development. Early writings of Piaget indicated that adolescents reached an equilibrium of formal thought at about the age fifteen (Inhelder & piaget, 1958). But Piaget himself, as well as Piagetian researchers, have more recently indicated that the chronological age at which formal thinking develops varies from one society

to another (Peaget, 1972) and that full development of this stage is reached by only a segment of normal adolescents and adults, although all adults develop formal operations in some domain.

Basic to much of the current practical research involving Piagetian theory is the assumption that students move through the arbitrarily defined Piagetian stages in a constant way, and in order to progress from one stage to another, they must be confronted only with those situations which they can understand in their present stage. A concrete thinker does not become a formal thinker by being confronted with formal operational tasks and concepts (Lawson & Renner, 1974). Concrete thinkers must meet concrete level tasks which will stimulate and challenge their mental ability to move to a higher level. Piaget reminds us that the concrete thinker begins by acting but: In formal thought there is a reversal of the direction of thinking between reality and possibility in the subjects' method of approach. Possibility no longer appears as an extension of an empirical situation or of actions actually performed. Instead, it is reality that is now secondary to possibility (Inhelder & Piaget, 1958, p. 251).

A study performed by Lawson, Blake and Nordland (1975) showed that for a group of science students with a mean age of 15 years, 5 months, 56% were concrete thinkers and only 8% were fully formal operational thinkers with the other 36% classified as early formal thinkers. Grant and Renner (1975) found that when

a sample of biology students were asked to explain their responses to a formal-concept test, 44% of them could be classified as concrete thinkers, another 18% merely guessed; the concrete thinkers needed concrete information as proof of their explanations and "when these thinkers are confronted with abstract concepts they focus their thoughts on things with thich they can cope" (Grant & Renner, 1975, p. 285). Thus many adolescents are in a transition state between concrete and formal thought. Their learning can be described as inconsistent (Walsh, 1981) and since cumulative evidence supports the idea that a majority of secondary students are remaining at the concrete level, research examining other factors such as instructional strategies, curriculum, and achievement must be conducted.

Achievement and Cognitive Level

The increased interest in the application of Piagetian theory to science and mathematics instruction, especially, has been triggered by this discrepancy in formal thought attainment and has coincided with a growing interest in the similarity between science thinking and formal reasoning. The knowledge of facts and concepts that students acquire is associated with the operational level they have entered. Thus, research has been conducted which employed formal-concept tests (Grant & Renner, 1975), teacher-made achievement tests (Coulter et al., 1981) and formal teaching methods (Sheehan, 1970) to examine this association. A study done by Marek (1981) concluded that the more formal operational students have a greater content

knowledge than the more concrete operational students. This same researcher found the same trend between cognitive development and IQ and between cognitive development and inquiry skills achievement. In a study investigating the effects of concrete and formal instructional procedures on students who had been classified as either concrete or formal (Sheehan, 1970), it was found that achievement was more durable for formal students than for concrete students with either concrete or formal instruction. Also, this achievement was greater regardless of instructional method (concrete or formal) and, finally, that concrete instruction was more effective than formal instruction with either concrete or formal students. Studies conducted by Cantu and Herron (1978) demonstrated that formal thinkers achieved more than concrete thinkers when either formal or concrete concepts were taught. Thus, the method of instruction as well as the level of cognitive thought and type of concept taught is significant to note.

But content of science subject matter is also a controlling factor in student understanding. "Much of what we teach in science appears to require formal operational thought" (Cantu & Herron, 1978, p. 143) but an elimination of formal concepts from the science curriculum would not be acceptable to science educators because many important ideas of science require formal reasoning for total understanding. Should the negative view be taken that the concrete thinker will never fully grasp the essential concepts of science courses? Piagetian researchers and practitioners (Cantu & Herron, 1978; Herron, 1975) have in-

dicated that this problem can be approached in two ways: either make the subject matter accessible to the concrete operational student or "encourage and assist (the student) in becoming formal" (Herron, 1975, p. 149). It cannot be said that the concrete thinker cannot solve problems. But the starting point for this student is always the real rather than the potential. The student can only reason from real observations and must extrapolate from these sensory experiences (Herron, 1975). The formal thinkers, when they are confronted with new problems, oftentimes revert to concrete patterns of thought in order to solve those problems. Results from a study examining the role of student preference in the measurement of cognitive level indicated that although students may possess formal thought ability, they may prefer to solve certain problem types by concrete methods (Dunlop & Fazio, 1977). This supports the theory of Piaget that mental development is not static but rather a development affected by the factors of maturation, experience, social transmission and selfregulation (equilibration) and the individual can fluctuate between concrete and formal reasoning. Perhaps it is the job of the educator to help the individual to meet new problems with the appropriate reasoning ability while encouraging the use of a higher level of reasoning.

An Instructional Implication

The evidence that adolescents exhibit concrete, transitional and formal thought patterns has many and varied implications for science education. To review Piagetian ideas, the factors which affect the development of one set of mental structures to another are: maturation, experience, social

transmission and selfregulation. Using these tenets, Lawson (1975) has outlined an instructional pattern in applying this theory to educational practice. Lawson would initiate instruction with the presentation of an undifferentiated whole followed by differentiation of this whole concept into its identifiable parts through concrete experiences. Then students would invent concepts employing symbolic notation which would interrelate the parts of the whole into patterns or concepts. Finally, students would perform discovery experiences in which new inventions, concepts are explored and applied to different situations (Lawson, 1975). Through this discovery process, students would be able to undergo selfregulation, the factor Piaget described as so crucial in the development of abstract thinking. Lawson himself described his instructional pattern as a microcosm of intellectual development in general. This instructional scheme is closely allied to Piagetian theory and incorporates the assumption that "The growth of formal thinking, as well as the age at which adolescence itself occurs...remain dependent on social as much as neurological factors" (Inhelder & Piaget, 1958, p. 337). The scheme designed by Lawson relies on these social factors and incorporates such classroom activities which allow for student-student interaction.

Regardless of the instructional strategy used, when the logic of the learner determines the curriculum, teachers must keep the intellectual level of the student in mind when planning lessons rather than basing the teaching strategies

on the intellectual capabilities of the teacher (Renner et al., 1976). Teachers could also follow the guidelines summarized by Walsh (1981) and:

1) present new material on the concrete level,
2) conduct group activities which encourage development of formal reasoning from concrete, and
3) pretest each student to determine cognitive level (p. 40).

Mental Tests

"Piaget's theory provides a clear, reasonable, and in many ways, testable theory of cognition, and so can serve as a guide for designing instructional systems. The testable aspect, however, is a potential source of difficulty and misunderstanding" (Maloney, 1981, p. 190). The Piagetian tests are approximately fifteen problem-oriented tasks which try to challenge student ability to identify and control variables, to use proportional thought and to use combinatorial reasoning abilities. The tester or interviewer is specially trained to conduct and interpret each task individually and to record observations of students as they respond to tasks.

Before discussing the research related to the use of specific mental tests it should be noted that substitution of PTIs for general intelligence tests is criticized and caution is recommended when using any test of mental measurement (Elkind, 1974). Elkind questions the use of Piagetian tasks to practical ends. He claims that Piaget examines part of the whole intellectual framework of the individual and that

the intelligence tests assess a broad range of abilities. The PTIs should not replace the established intelligence tests or achievement tests. Elkind states further:

> A great deal of theoretical and empirical work needs to be done before the information provided by Piagetian tasks will be relevant to laymen, educators, and clinicians. That is to say, until educators and clinicians come to see their problems in cognitive developmental terms, a subject's performance on a scale of Piagetian tasks will have little practical value for them. And, if a test has no practical value, it will not be used (1974, p. 158).

There is evidence from the studies referred to in this research that considerable "theoretical and empirical work" has already been done in this area. The PTIs which had been used exclusively by researchers in determining the level of operational thought have now become the model upon which new instruments are developed. These new instruments include paper and pencil written tests (Gabel, 1979; Grant & Renner, 1975; Tobin & Capie, 1980), new PTIs developed independently (Sayre & Ball, 1975), and even electronic apparatus which is equivalent to the first chemical experiment of Piaget (DeLuca, 1977). The attempt with all of the above has been to make measuring mental development more practical for the teacher. Determining the cognitive levels of students should be the initial step in teaching, before planning and sequencing of science instruction (Renner et al., 1976, Sayre & Ball, 1975).

Many of the studies which have conducted interviews similar to those of Piaget recognized the importance of diagnosing levels of intellectual development of students and have admitted that the interview process is very time consuming and difficult to administer (Grant & Renner, 1975; Lawson, 1975; Marek, 1981; Sayre & Ball, 1975). Because the requirements of PTIs are very difficult to meet, there has been a definite movement in the direction of a more rapidly administered and scored procedure. The most common form is some type of paper and pencil test that can be administered to large groups in a relatively short time. The Longeot Test is a paper and pencil test that has overcome the many drawbacks of the PTIs and similar assessments of mental development. This instrument is described in detail in Chapter 3 of this study.

## Statement of the Problem

Traditionally, student mental growth has been measured by Piagetian Task Instruments (PTIs) which Piaget designed to identify student levels of reasoning: namely, sensori-motor, pre-operational, concrete and formal. The problem with using PTIs was the difficulty and time required in administering these examinations. Teachers need a practical yet reliable assessor of cognitive ability. Therefore, this research used the Longeot Test to test the practicality of assessing student cognitive levels in the classroom situation. The Longeot test is a paper and pencil test which can be administered to a relatively large group of students and assessed quickly. It consists of approximately thirty objective questions and the responses of students

to this examination have proven to be reliable indicators of their ability to think formally (Ward, Nurrenbern, Lucas, and Herron, 1981). Teachers whose goal is to individualize instruction may also look to some readily available student characteristics such as: age, sex, educational level of parents and course instruction to help them understand at what level their students may be thinking. Measuring cognitive levels will give a valuable index of student intellectual potential, useful for the teacher in developing classroom curricula. This index will help the teacher recognize student differences and thereby aid in the choice of instructional meterials and techniques.

## Purpose of the Study

The questions this research addressed were: How can student mental growth be accurately measured by the classroom teacher? And, is there a relationship between cognitive level and achievement level, age, sex, educational level of parents, and type of science course; and can these factors have predictive value for teachers? This research study has applied Piagetian theory to a practical situation by assessing students' levels of cognitive development as either concrete or formal operational, according to the Piagetian model and by correlating this performance level of mental growth to available student characteristics.

## Objectives

The primary objectives tested in this study were:

1. to assess reasoning levels of students using the Longeot Test.

2. to compare the background of each student with the student's reasoning ability.

3. to identify which factors would best determine a student's reasoning level on the Longeot Test.

## Methodology

### Subjects

A sample of adolescent boys and girls was chosen from various junior and senior high schools in the Upper Cumberland Region. The range in age for these students was fourteen to seventeen and it was necessary for these students to be enrolled in a science course: biology, general science, chemistry, physical science, or physics.

### Procedure

Students were administered the Longeot Test during a class period and were asked to complete a student information sheet attached to the Longeot answer sheet. Standardized achievement scores were also obtained for each student. Statistical techniques for this study included tests for significance: analysis of variance, chi-square and correlational tests using Pearson r. The .05 level of significance was chosen as indicative of statistical significance for all tests.

## Chapter II

### Research Procedures

This chapter contains a discussion of the population used in this study, as well as, the materials including the test instrument and the methodology employed to obtain the necessary data. The hypotheses under study are also presented.

### Population and Sample

The sample for this study consisted of 636 boys and girls from nine schools located in the Upper Cumberland Region of Tennessee. The population consisted of 22 schools from the 14 county region known as the Upper Cumberland District. Letters were written to thirteen schools in this area requesting their cooperation in releasing scores on the achievement of some of their science students and in testing these same students with the use of the Longeot Test. Of the thirteen schools, nine agreed to participate and were given the results of the study. The attempt was made by the researcher to obtain various types of science classes: bilogy, general science, physical science, and physics, and representative classes from each grade level in order to have all age levels from 14 through 17 represented. The sample is a good representation of the region. Of the 636 students, there were 336 females and 300 males. The percentage of students in the various science classes is included in table 1 which follows:

TABLE I

| Science Course | Number of Students | Percent of Sample |
|---|---|---|
| biology | 220 | 34.4 |
| general science | 110 | 17.3 |
| chemistry | 127 | 20.0 |
| physical science | 119 | 18.7 |
| physics | 60 | 9.4 |

## Materials

The materials for this study consisted of specific data for each student in the sample. Standardized achievement scores were obtained with the permission of school principals for 501 of the 636 students. These composite scores were taken from the student's most recent standardized achievement test and represented more than any other criterion the general achievement percentile of the student. The other materials used were the test instrument, the Longeot Test, and student background information.

### Longeot Test

The Longeot Test is a paper and pencil test introduced in 1962 and successfully used to assess the cognitive levels of large numbers of students. It was formally evaluated in research conducted by Ward, Nurrenbern, Lucas and Herron (1981). There was an increase in the correlation between the classifica-

tion based on the Longeot Test and those made using other Piagetian Test Instruments (PTIs) from .49 to .62 (n=20). Concerning reliability, the internal consistency measurements ranged from .72 to .78 over a wide range of class types (Ward et al, 1981). The validity, though more difficult to assess, was also substantiated. Scores on the Longeot Test showed a significant correlation ($r = .62$, $p$ .01) with the sum of two Piagetian tasks. Support for the fact that the Longeot Test assesses cognitive development was shown by the fact that there were fewer concrete students in science courses where presection factors discouraged their admittance. The KR-20 reliability co-efficient for the Longeot Test was determined by Lawson and Blake (1976) to be .85. Chi-square analysis of their data yielded a significant relationship between this classification instrument and three PTIs ( $X^2 = 17.9$: df = 9: p .02).

In a study comparing the predictive success of the Longeot Test versus an intelligence test, it was found that the construct measured by the former was more clearly defined and therefore preferable for use (Carlson, 1977). Not all paper and pencil tests have correlated highly with PTIs (Tschopp & Kurdek, 1981) but efforts to validate the Sheehan 1970 version of the Longeot Test showed that it did provide a measure of concrete versus formal operations (Farrell, 1980) although the number of formal thinkers in this study appeared to be inflated. In this case the inflation may have been due to a question on the test involving combinatorial logic. The student was asked to write

down the possible combinations to a question and according to Piaget writing them down does not necessarily mean the student can use the combinatorial system to make inferences. Because the Longeot Test is almost entirely multiple choice, no justification for answers is required and an over-estimation of the number of formal students in this example was possible. Additional use of the Longeot Test was shown in a study evaluating high school chemistry courses which promoted formal reasoning in students by instructing them at their own cognitive level (Smith & Van Egerer, 1977), in a study examining sex differences in concrete and formal reasoning ability (Lawson, 1975), and in a study attempting to train thirty high school students to control variables (Lawson, Blake, and Nordland, 1975).

In conclusion, there seems to be little doubt that the Longeot Test does provide a measure of concrete versus formal operational thinking. It is a test that is easy to administer with a minimum of guidance.

Student Background Information

Information was obtained from each student relative to the age, sex, educational level of parents and type of science course of the student. It was compiled on the first page of the Longeot Test Answer Booklet and a copy of the student background information is found in the Appendix.

## Procedures

Copies of the Longeot Test translated by Sheehan, (1970) were obtained and distributed to the science teachers along with

answer sheets for the test and the attached student background information form. Teachers were given specific written instructions on how to administer the Longeot Test. The student background information was completed by each student prior to the administration of the test.

The Longeot Test was administered to 636 students between January and March of 1982 during a single class period. The test was divided into four parts, as follows:

Part I - 5 minutes

Part II - 15 minutes

Part III - 5 minutes

Part IV - 20 minutes

The test consisted of twenty eight questions requiring either concrete or formal operational reasoning and the final score was computed by giving concrete items a weight of 1 and the formal items a weight of 2. The revised classification of test items (Ward et al, 1981) was used as a basis for scoring and test scores ranged from 0 to 42. Scores and background information were coded for use in SPSS (Statistical Package for the Social Sciences) programs. The data were analyzed to observe the distribution of concrete and formal subjects for each group of students. Statistical techniques including analysis of variance, analysis of covariance, chi-square and multiple correlation and regression were used to compare differences between groups of students according to difference characteristics. Results of correlational analysis were examined for predictive value of independent variables on the dependent variable (Longeot Test Scores). For all analysis the .05 level

of confidence was chosen as indicative of statistical significance.

## Hypotheses

The F-Ratio statistic was used to establish rejection or no rejection of the following null hypotheses:

1. There is no statistically significant difference by age on the achievement levels of students.
2. There is no statistically significant difference by age on the reasoning levels of students as measured by the Longeot Test.
3. There is no statistically significant difference by sex on student achievement level.
4. There is no statistically significant difference by sex on student reasoning level.
5. There is no statistically significant difference by educational level of the father on student achievement level.
6. There is no statistically significant difference by educational level of the father on student reasoning level.
7. There is no statistically significant difference by educational level of the mother on student achievement level.
8. There is no statistically significant difference by educational level of the mother on student reasoning level.
9. There is no statistically significant difference by the type of science course in which students enrolled on student achievement level.
10. There is no statistically significant difference by the type of science course in which students enrolled on student reasoning level.

## Symbols

The following symbols were used in the presentation of data:

The dependent variable used in this study was:

Y = the Longeot Test score (Lont)

The independent variables used in this study were:

$X_1$ = achievement level (ACH)

$X_2$ = students 14 years of age (AGE)

$X_3$ = students 15 years of age (AGE)

$X_4$ = students 16 years of age (AGE)

$X_5$ = students 17 years of age and above (AGE)

$X_6$ = female students (SEX)

$X_7$ = male students (SEX)

$X_8$ = educational level of father - 8th grade (FAT)

$X_9$ = educational level of father - attended but did not complete high school (FAT)

$X_{10}$ = educational level of father - 12th grade (FAT)

$X_{11}$ = educational level of father - attended but did not complete collete (FAT)

$X_{12}$ = educational level of father - college graduate (FAT)

$X_{13}$ = educational level of mother - 8th grade (MOT)

$X_{14}$ = educational level of mother - attended but did not complete high school (MOT)

$X_{15}$ = educational level of mother - 12th grade (MOT)

$X_{16}$ = educational level of mother - attended but did not complete college (MOT)

$X_{17}$ = educational level of mother - college graduate (MOT)

$X_{18}$ = biology students (SCI)

$X_{19}$ = general science students (SCI)

$X_{20}$ = chemistry students (SCI)

$X_{21}$ = physical science students (SCI)

$X_{22}$ = physics students (SCI)

$\bar{X}$ = mean of sample data

Independent variables $X_2$ through $X_{22}$ are categorical variables.

The following symbols were used for reporting the results:

r = coefficient of correlation

RSQ = coefficient of determination

.05 = level of confidence used for statistical significance

.01 = level of confidence used for statistical significance

n = sample size

ANOVA = analysis of variance

ANCOVA = analysis of covariance

## Chapter III

## ANALYSIS, DISCUSSION AND RECOMMENDATIONS

### Analysis of Data

Test scores and background information obtained for each student and analyzed statistically to determine if achievement, age, sex, educational level of parents and/or type of science course in which student was enrolled were significantly related to performance on the Longeot Test. Analysis of variance was used to determine if a statistically significant difference at the .05 level existed between scores on the Longeot Test over each of the categorical classifications of age, sex, educational level of the father, educational level of the mother, and type of science course in which the student was enrolled. Multiple correlation was used to determine the correlational relationships among different variables and to select the best variables for predicting reasoning level. When statistically significant differences were found to occur over particular categorical subgroups on both the standardized achievement scores and the dependent variable, analysis of covariance was employed. Chi-square was used to test for trends in categorical variables with respect to the dependent variable. Appropriate data using the latter technique as well as frequency tables for the Longeot Test are listed in the Appendix.

Comparison of age of Students with Achievement levels and with Longeot Test scores using one-way ANOVA.

the null hypothesis stating that there was no significant difference by age on achievement level was not rejected but the null hypothesis stating that there was no significant difference by age on reasoning level was rejected.

Comparison by Sex of Students using Analysis of Variance

The following null hypothesis was used:

$\bar{X}_6 = \bar{X}_7$, to determine if there was any significant difference by sex on student achievement or reasoning level.

TABLE III

COMPARISON BY SEX WITH ACH AND LONT

| | Means for Female and Male Groups | | | | | | |
|---|---|---|---|---|---|---|---|
| Creterion | $\bar{X}_6$ | $\bar{X}_7$ | Total | $df_1$ | $df_2$ | F-Ratio | Sign. |
| n | 269 | 232 | 501 | | | | |
| $X_1$ | 68.17 | 64.78 | 66.60 | 1 | 499 | 2.32 | 0.128 |
| n | 336 | 300 | | | | | |
| Y | 18.20 | 18.92 | 18.54 | 1 | 634 | 1.22 | 0.269 |

The F values of 2.32 and 1.22 at levels of significance above .05 indicated that the obtained results could be due to chance alone rather than influenced by sex of the student. From these statistics there was no significant difference by sex on achievement levels or on reasoning levels at the .05 level. However, the mean of the female group was above that for males on the independent variable (68.17 and 64.78, respectively) and the mean of the male group on the dependent variable (18.92) was

The following null hypotheses were tested:

$\bar{X}_2 = \bar{X}_3 = \bar{X}_4 = \bar{X}_5$

TABLE II

COMPARISON OF AGE WITH ACH AND LONT

| | Means for Age Groups | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Criterion | $\bar{X}_2$ | $\bar{X}_3$ | $\bar{X}_4$ | $\bar{X}_5$ | Total | $df_1$ | $df_2$ | F-R | Sign. |
| n | 73 | 176 | 132 | 120 | 501 | 3 | 497 | 0.97 | 0.40 |
| $X_1$ | 68.68 | 68.03 | 63.69 | 66.44 | 66.60 | | | | |
| n | 120 | 217 | 160 | 130 | 636 | 3 | 632 | 11.75 | 0.000 |
| Y | 16.70 | 17.44 | 18.51 | 21.87 | 18.54 | | | | |

The F-Ratio of 11.75 at the 0.000 level of significance indicated a significant difference by age on the Longeot Test scores, or reasoning level, but not on the achievement percentiles. The .05 level of confidence was not achieved on the significance test of achievement by age (0.40). An examination of the means for each age group on the achievement variable indicates that the youngest group, the 14 year olds had the highest achievement percentiles and the trend of mean achievement level decreases as age increases. In the dependent variable, the trend is the reverse with the mean of the Longeot Test scores of the younger students lowest and increasing as the age of students increases. This observation prompted further analysis of the data using analysis of covariance techniques and these data are listed in Table 7. From the results thus far presented,

above that of the females (18.20), which prompted further analysis using analysis of covariance. The results for the latter technique are listed in Table 7.

Comparison of Educational Level of the Father using ANOVA

To identify any significant difference by educational level of the father on achievement level and reasoning level a one-way ANOVA was used based on the following hypotheses:

$$\bar{X}_8 = \bar{X}_9 = \bar{X}_{10} = \bar{X}_{11} = \bar{X}_{12}$$

TABLE IV

COMPARISON OF FAT WITH ACH AND LONT

| | Means for Educational Levels | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Criterion | $\bar{X}_8$ | $\bar{X}_9$ | $\bar{X}_{10}$ | $\bar{X}_{11}$ | $\bar{X}_{12}$ | Total | $df_1$ | $df_2$ | F-B | Sign. |
| n | 86 | 107 | 151 | 51 | 100 | 195 | | | | |
| $X_1$ | 59.26 | 57.82 | 67.97 | 72.96 | 77.30 | 66.66 | 4 | 490 | 11.81 | 0.000 |
| n | 106 | 147 | 199 | 60 | 116 | 628 | | | | |
| Y | 15.68 | 16.40 | 18.96 | 21.40 | 21.62 | 18.53 | 4 | 623 | 12.93 | 0.000 |

The F-Ratio of 11.81 indicates a significant difference by educational level of the father on achievement levels and an F-Ratio of 12.93 shows a significant difference by educational level of the father on Longeot Test scores at better than the .05 level of confidence. Based on these results the null hypotheses: $\bar{X}_8 = \bar{X}_9 = \bar{X}_{10} = \bar{X}_{11} = \bar{X}_{12}$ were rejected. To determine whether the significant differences found were due to the influence of achievement levels or by the educational levels themselves, an

analysis of covariance test was used. Results are listed in Table VII.

Comparison of Educational Level of the Mother using ANOVA

To determine if there was any significant difference by educational level of the mother on achievement levels or on reasoning levels, a one-way ANOVA was used based on the following null hypotheses:

$$\bar{X}_{13} = \bar{X}_{14} = \bar{X}_{15} = \bar{X}_{16} = \bar{X}_{17}$$

TABLE V

COMPARISON OF MOT WITH ACH AND LONT

| | Means for Educational Levels | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Criterion | $\bar{X}_{13}$ | $\bar{X}_{14}$ | $\bar{X}_{15}$ | $\bar{X}_{16}$ | $\bar{X}_{17}$ | Total | $df_1$ | $df_2$ | F-R | Sign. |
| n | 59 | 120 | 190 | 40 | 89 | 498 | | | | |
| $X_1$ | 56.28 | 58.66 | 68.96 | 72.17 | 76.94 | 66.66 | 4 | 493 | 11.31 | 0.000 |
| n | 75 | 163 | 242 | 49 | 103 | 632 | | | | |
| Y | 15.25 | 16.24 | 19.14 | 20.91 | 22.00 | 18.53 | 4 | 627 | 13.41 | 0.000 |

The F-Ratios of 11.31 and 13.41 obtained at the 0.000 level of confidence indicated that there was a significant difference by educational level of the mother on achievement levels and on reasoning levels. The null hypotheses were rejected. Further analysis of this categorical variable with achievement levels held constant were performed using analysis of covariance and results are listed in Table VII.

Comparison of the Type of Science Course in which Student Enrolled using ANOVA

To determine whether there was any significant difference by type of science course on achievement levels or on reasoning levels, a one-way ANOVA was used based on the following null hypotheses:

$$\bar{X}_{18} = \bar{X}_{19} = \bar{X}_{20} = \bar{X}_{21} = \bar{X}_{22}$$

TABLE VI

COMPARISON OF SCI WITH ACH AND LONT

| | Means of Science Courses | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Criterion | $\bar{X}_{18}$ | $\bar{X}_{19}$ | $\bar{X}_{20}$ | $\bar{X}_{21}$ | $\bar{X}_{22}$ | Total | $df_1$ | $df_2$ | F-R | Sign. |
| n | 197 | 58 | 110 | 84 | 51 | 500 | | | | |
| $X_1$ | 65.84 | 44.84 | 67.73 | 76.23 | 76.86 | 66.69 | 4 | 495 | 19.04 | 0.000 |
| n | 219 | 110 | 127 | 119 | 60 | 635 | | | | |
| Y | 17.65 | 12.14 | 22.14 | 19.21 | 24.76 | 18.54 | 4 | 630 | 41.64 | 0.000 |

The F-Ratio of 19.04 obtained at the 0.000 significance level on the independent variable indicated that there was a significant difference by the type of science courses in which students enrolled. The F-Ratio of 41.64 at the 0.000 significance level on the dependent variable indicated that there was a significant difference by the type of science courses in which students enrolled and their performance on the Longeot Test. Therefore, the null hypotheses were rejected. Further analysis of this categorical variable was conducted using analysis of covariance and the results are listed in Table VII.

Analysis of Covariance

This technique was used for the purpose of controlling the independent predictor variable, ACH, and thus examining the possible main effects of the categorical variables: AGE, SEX, FAT, MOT, and SCI on Lont.

TABLE VII

ANALYSIS OF ANCOVA USING CATEGORICAL VARIABLES

| Independent variable | Mean | n | F-Ratio | Signif. of F |
|---|---|---|---|---|
| AGE | 19.12 | 501 | 14.29 | 0.000 |
| SEX | 19.12 | 501 | 8.39 | 0.004 |
| FAT | 19.13 | 495 | 1.80 | 0.127 |
| MOT | 19.12 | 498 | 2.55 | 0.038 |
| SCI | 19.14 | 500 | 13.55 | 0.000 |

The F-Ratios shown in Table VII indicated that after controlling for the ACH variable, AGE, SEX, and SCI remained significant categorical variables at or below the .01 level of confidence, and MOT remained a significant categorical variable at the .05 level. Only the F-Ratio for FAT was not statistically significant at the .05 level.

Correlational Analysis

The Pearson product correlation coefficient was computed between the achievement percentiles and the Longeot Test scores. The obtained value of r = 0.635 indicates a statistically significant and moderately strong relationship between the two

variables. This also determines the predictability between the two at approximately 40 percent (R-Squared = 0.403). This positive linear relationship indicates that as achievement percentile scores increase there is usually a corresponding increase in the Longeot Test scores. Of the 6.0 percent of students who scored in the lower fifth percent on the achievement percentile, 96.7 percent were judged as concrete operational thinkers on the Longeot Test. Of the 35.9 percent of students who scored in the upper fifth on the achievement percentile measure, 65.6 percent were judged to be at the formal (abstract reasoning) operational level on the Longeot Test.

Discussion of Findings

The significance of the F-Ratio using ANOVA with respect to students grouped by age, sex, by educational level of the father, educational level of the mother, and by type of science course indicated that the differences found between these groups were beyond chance expectation. These significant differences can be attributed to the fact that these factors have affected the performance of the students on the reasoning abilities test.

In terms of AGE, this study showed age as a determining factor of reasoning level. The general trend within the 14 to 17 year range was an increase in abstract reasoning ability with age. Twenty percent of the 14 year olds were formal thinkers but 45.3 percent of the 17 year olds had reached this level of reasoning. This result is in agreement with recent investigation of age and cognitive development and supports the revised Piagetian chronology. A majority of graduating seniors in this sample were still thinking concretely. The educational

implications in terms of mode of instruction and level of instructional materials for these students may need further examination.

Results of this study showed that the greater percentage of formal thinkers were male (53.7 percent) as opposed to female (46.3 percent). This was in agreement with research that found in males a greater ability to solve problems involving proportions and combinatorial logic and manipulation of number variables.

The crosstabulations of LONT with FAT revealed a gradual and significant increase in the percentage of formal thinking students with the percent greatest by those students whose fathers' had the highest level of education, a college degree.

The same trend was noted for the educational level of the mother. The percentage of formal thinking students increased as the degree of educational training of the mothers increased. Although fewer mothers of the students sampled went beyond high school (24.1 percent) as compared to the fathers (28.1 percent), the significance of the F value for MOT on the covariance test indicated that this variable is a more reliable determinant of reasoning level than is the FAT.

Most students sampled were in biology courses (34.5 percent), then chemistry had the next largest percentage (20.0 percent). Since biology is a popular science subject it may be helpful to biology teachers to note that only 31.1 percent of these students were operating at the formal level. For chemistry, with an emphasis on more abstract concept understanding, the

percentage was 44.1 percent or less than half of the chemistry students thinking in abstract terms; and for physics, of those few students who selected this course, 61.7 percent were at the formal operational stage. These results indicate that the Longeot Test has indeed assessed cognitive development because fewer concrete students were in those science courses where pre-selection factors had discouraged their entry. For general science and physical science where pre-selection has not been involved to a great extent 92.7 percent of students in general science were thinking on a concrete level and in physical science, 69.7 percent were thinking on a concrete level.

This study was concerned with the practical implications of Piagetian theory, rather than with how a student thinks or develops cognitive structures. An investigation of student characteristics readily available to teachers has revealed information which determines in part at what level a student is reasoning. The significant differences found in correlating these variables support the research that indicates the presence of two developmental stages in adolescence, that males score higher on a test of reasoning ability based on the Piagetian model than females, and that there is a positive correlation between achievement level and reasoning level.

For teachers who have easy access to student achievement levels, especially, this information would be a successful indicator of how their students were reasoning. But because the predictive value of achievement level was slightly less than fifty percent, the best measure of cognitive development for

adolescents would be the use of the Longeot Test itself. The results of this study support past research that validate this instrument as a measure of concrete and formal thought; and the fact that all sample tests distributed to the schools were completed in the time allocated and returned for evaluation is further proof of its administrative simplicity.

## Recommendations

Further investigation into student achievement levels, especially as they relate to the student's reasoning abilities, may uncover what kind of relationship exists between the two variables. A coefficient of determination of .40 indicates that 60 percent of the variance is unaccounted for and needs further investigation. Experimentation with additional factors using Piagetian "experience", "social transmission" and "equilibration" will provide information into what type of relationship exists and increase the RSQ or predictability of the relationship. But from the results of this study, a correlation has been found which will add meaning to the thesis put forth by Piaget and will add assistance to teachers who are willing to put theory to practical use. Additional aid to teachers would focus on research which dealt with the effects of various disciplines, instructional strategies and instructional materials on the development of the mental structures required by adolescents for formal reasoning. For science teachers, an examination of content in relation to level of understanding and reasoning ability of students would be a successful first step in developing curricula and teaching styles that meet the needs of each student.

# APPENDIX

Frequency Distribution for Longeot Test (Y)

| Test Score | Absolute frequency | Relative frequency |
|---|---|---|
| 1 | 1 | 0.2 |
| 2 | 1 | 0.2 |
| 3 | 10 | 1.6 |
| 4 | 9 | 1.4 |
| 5 | 8 | 1.3 |
| 6 | 15 | 2.4 |
| 7 | 12 | 1.9 |
| 8 | 18 | 2.8 |
| 9 | 22 | 3.5 |
| 10 | 24 | 3.8 |
| 11 | 16 | 2.5 |
| 12 | 23 | 3.6 |
| 13 | 25 | 3.9 |
| 14 | 31 | 4.9 |
| 15 | 23 | 3.6 |
| 16 | 34 | 5.3 |
| 17 | 25 | 3.9 |
| 18 | 25 | 3.9 |
| 19 | 23 | 3.6 |
| 20 | 33 | 5.2 |
| 21 | 30 | 4.7 |
| 22 | 23 | 3.6 |
| 23 | 21 | 3.3 |
| 24 | 20 | 3.1 |
| 25 | 27 | 4.2 |
| 26 | 25 | 3.9 |
| 27 | 19 | 3.0 |
| 28 | 22 | 3.5 |
| 29 | 14 | 2.2 |
| 30 | 10 | 1.6 |
| 31 | 11 | 1.7 |
| 32 | 5 | 0.8 |
| 33 | 5 | 0.8 |

| Test Score | Absolute frequency | Relative ferquency |
|---|---|---|
| 34 | 7 | 1.1 |
| 35 | 6 | 0.9 |
| 36 | 5 | 0.8 |
| 37 | 2 | 0.3 |
| 38 | 5 | 0.8 |
| 40 | 1 | 0.2 |
| Mean 18.54 | Standard Error | 0.321 |
| Mode 16 | Standard Deviation | 8.104 |
| Median 18.34 | | |

Concrete - Formal Classification Scheme

| Classification | Score |
|---|---|
| Concrete | 0 - 22 |
| Formal | 23 - 42 |

(adapted from Ward et al, 1981)

Cumulative frequency of concrete level thinkers was 67.8%

Cumulative frequency of formal level thinkers was 32.2%

Cross-tabulations of LONT by AGE

| Count / Row % / Col % / Tot % | AGE 14 | 15 | 16 | 17 & up | Row Total |
|---|---|---|---|---|---|
| C | 96 | 152 | 107 | 76 | 431 |
| | 22.3 | 35.3 | 24.8 | 17.6 | |
| | 80.0 | 70.0 | 66.9 | 54.7 | |
| LONT | 15.1 | 23.9 | 16.8 | 11.9 | 67.8% |
| F | 24 | 65 | 53 | 63 | 205 |
| | 11.7 | 31.7 | 25.9 | 30.7 | |
| | 20.0 | 30.0 | 33.1 | 45.3 | |
| | 3.8 | 10.2 | 8.3 | 9.9 | 32.2% |
| | 120 | 217 | 160 | 139 | 636 |
| | 18.9 | 34.1 | 25.2 | 21.9 | 100% |

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